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(71)出願人　000005108
株式会社日立製作所
東京都千代田区神田駿河台四丁目６番地

(72)発明者　中谷　亮一
東京都国分寺市東恋ヶ窪一丁目280番地
株式会社日立製作所中央研究所内

(72)発明者　星野　勝美
東京都国分寺市東恋ヶ窪一丁目280番地
株式会社日立製作所中央研究所内

(72)発明者　星屋　裕之
東京都国分寺市東恋ヶ窪一丁目280番地
株式会社日立製作所中央研究所内

(74)代理人　弁理士　平木　祐輔

最終頁に続く

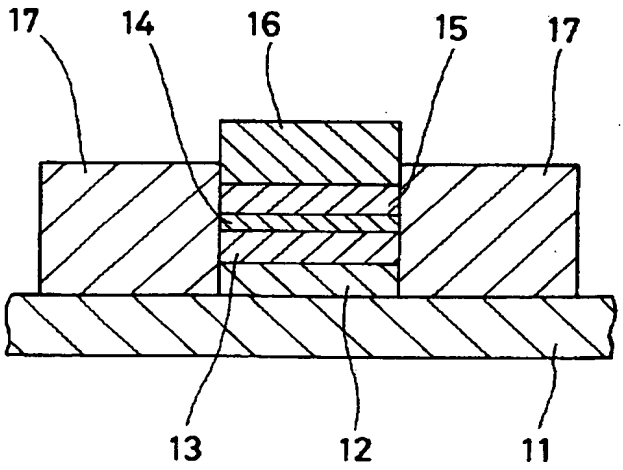
(54)【発明の名称】　磁気抵抗効果膜、磁気抵抗効果型ヘッド及び磁気記録再生装置

(57)【要約】

【目的】　酸化物系反強磁性材料を用いた多層膜磁気抵抗効果素子の構造を提供する。

【構成】　磁気抵抗効果材料として、１層の磁性層に反強磁性層からの交換バイアス磁界を印加し、１層の磁性層には直接には反強磁性層からの交換バイアス磁界を印加しない多層膜を用いた磁気抵抗効果型ヘッドにおいて、酸化物を主成分とする高耐食性の反強磁性層１６を、多層膜を形成した基板１１から見て上記２層の磁性層１３，１５よりも遠い側に形成する。さらに、電極を形成する部分の反強磁性層を除去した後、電極１７，１７を形成する。

【効果】　本発明の磁気抵抗効果素子は、高感度及び優れた軟磁気特性を示す。また、誘導型磁気ヘッドと組み合わせることにより、高密度磁気記録再生装置に有利な高性能磁気ヘッドを得ることができる。



【特許請求の範囲】

【請求項１】　基板上に設けられた２層の磁性層と、前記２層の磁性層の間に設けられた非磁性層と、前記２層の磁性層のうちの一方の磁性層に接触して設けられた反強磁性層とを含む多層膜からなり、前記反強磁性層は酸化物を主成分とし前記基板に対して前記２層の磁性層よりも遠い側に設けられており、前記反強磁性層に接触していない磁性層と前記基板との間には反強磁性層が設けられていないことを特徴とする多層磁気抵抗効果膜。

【請求項２】　基板と、非磁性層で分離された２層の磁性層と該２層の磁性層のうちの一方の磁性層に接触して設けられた反強磁性層とを含む多層膜と、一対の電極とを備える磁気抵抗効果型ヘッドであって、
前記反強磁性層は酸化物を主成分とし前記基板に対して前記２層の磁性層よりも遠い側に設けられており、前記反強磁性層に接触していない磁性層と前記基板との間には反強磁性層が設けられておらず、前記一対の電極は少なくとも反強磁性層以外の前記多層膜の層に接触していることを特徴とする磁気抵抗効果型ヘッド。

【請求項３】　基板と、非磁性層で分離された２層の磁性層と該２層の磁性層のうちの一方の磁性層に接触して設けられた反強磁性層とを含む多層膜と、一対の電極とを備える磁気抵抗効果型ヘッドであって、
前記反強磁性層は酸化物を主成分とし前記基板に対して前記２層の磁性層よりも遠い側に設けられており、前記一対の電極の基板法線方向に前記反強磁性層が存在しないことを特徴とする磁気抵抗効果型ヘッド。

【請求項４】　基板と、非磁性層で分離された２層の磁性層と該２層の磁性層のうちの一方の磁性層に接触して設けられた反強磁性層とを含む多層膜と、一対の電極とを備える磁気抵抗効果型ヘッドであって、
前記反強磁性層は酸化物を主成分とし前記基板に対して前記２層の磁性層よりも遠い側に設けられており、前記一対の電極の基板法線方向に前記多層膜が存在しないことを特徴とする磁気抵抗効果型ヘッド。

【請求項５】　基板と、非磁性層で分離された２層の磁性層と該２層の磁性層のうちの一方の磁性層に接触して設けられた反強磁性層とを含む多層膜と、一対の電極とを備える磁気抵抗効果型ヘッドであって、
前記反強磁性層は酸化物を主成分とし前記基板に対して前記２層の磁性層よりも遠い側に設けられており、前記一対の電極は前記多層膜の積層端面において前記多層膜と接触していることを特徴とする磁気抵抗効果型ヘッド。

【請求項６】　前記一対の電極と基板との間にＣｏ系合金からなる磁性層が形成されていることを特徴とする請求項２～５のいずれか１項記載の磁気抵抗効果型ヘッド。

【請求項７】　基板上にバッファ層、磁性層、非磁性層、磁性層及び酸化物を主成分とする反強磁性層をこの順序で積層して設けられた多層膜と、前記基板上に前記多層膜の積層端面と接触する部分を有するように設けられた一対の電極とを含むことを特徴とする磁気抵抗効果型ヘッド。

【請求項８】　基板上にバッファ層、磁性層、非磁性層、磁性層及び酸化物を主成分とする反強磁性層をこの順序で積層して設けられた多層膜と、前記基板上に前記多層膜の積層端面と接触する部分を有するように設けられた一対の電極とを含み、前記一対の電極と基板との間にＣｏ系合金からなる磁性層が形成されていることを特徴とする磁気抵抗効果型ヘッド。

【請求項９】　前記反強磁性層はＮｉ－Ｏ系反強磁性層であることを特徴とする請求項２～８のいずれか１項記載の磁気抵抗効果型ヘッド。

【請求項１０】　前記多層膜は２層の磁気シールド層の間に挟まれて設けられていることを特徴とする請求項２～９のいずれか１項記載の磁気抵抗効果型ヘッド。

【請求項１１】　請求項１０に記載の磁気抵抗効果型ヘッドと、磁気的に結合された一対の磁極及びコイルを備える誘導型磁気ヘッドとを組み合わせて設けたことを特徴とする複合型磁気ヘッド。

【請求項１２】　磁気記録媒体と、請求項２～１０のいずれか１項に記載の磁気ヘッドと、前記磁気記録媒体と前記磁気ヘッドとを相対的に駆動する駆動手段と、前記磁気ヘッドに接続された記録再生信号処理系とを含むことを特徴とする磁気記録再生装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、高い磁気抵抗効果を有する多層磁気抵抗効果膜、その多層磁気抵抗効果膜を用いた磁気抵抗効果型ヘッド及び磁気記録再生装置に関する。

【０００２】

【従来の技術】磁気記録の高密度化に伴い、再生用磁気ヘッドに用いる磁気抵抗効果材料として、高い感度を示す材料が求められている。最近、Ｄｉｅｎｙらによるフィジカル・レビュー・Ｂ（Physical Review B）、第４３巻、第１号、１２９７～１３００ページに記載の「軟磁性多層膜における巨大磁気抵抗効果」（Giant Magnetoresistance in Soft Ferromagnetic Multilayers）のように２層の磁性層を非磁性層で分離し、一方の磁性層に反強磁性層からの交換バイアス磁界を印加する方法が考案された。この多層膜は一層の磁性層の厚さが薄いため、磁気抵抗効果素子を形成した時の反磁界係数が小さく、このため、低い磁界で磁気抵抗効果を示す。また、磁気抵抗変化量も大きい。

【０００３】

【発明が解決しようとする課題】上記フィジカル・レビュー・Ｂ（Physical Review B）に記載の多層膜には、Ｆｅ－Ｍｎ系合金からなる反強磁性層が用いられてい

る。しかし、Ｆｅ－Ｍｎ系合金は耐食性が悪く、それを用いた磁気抵抗効果素子の信頼性を低下させる。そこで、反強磁性材料としてＦｅ－Ｍｎ系合金に代わって耐食性の優れたＮｉ－Ｏ系酸化物等の酸化物系反強磁性材料を用いることが考えられる。しかし、酸化物系反強磁性層の上に形成した磁性層は軟磁気特性が劣化し、磁気抵抗効果素子の感度を低下させる。そこで、磁性層上に酸化物系反強磁性層を形成すると、磁性層の軟磁気特性は向上するが、酸化物系反強磁性層は電気抵抗率が高く、多層膜上に電極を形成してもセンス電流を流すことができない。

【０００４】本発明の目的は、耐食性に優れた高感度な多層磁気抵抗効果膜、その多層磁気抵抗効果膜を用いた高感度な磁気抵抗効果型ヘッド及び磁気記録再生装置を提供することにある。

【０００５】

【課題を解決するための手段】本発明者等は、多層磁気抵抗効果膜について鋭意研究を重ねた結果、基板上に設けられた２層の磁性層と、２層の磁性層の間に設けられた非磁性層と、２層の磁性層のうちの一方の磁性層に接触して設けられた反強磁性層とを含む多層膜からなり、反強磁性層は酸化物を主成分とし基板に対して２層の磁性層よりも遠い側に設けられており、反強磁性層に接触していない磁性層と基板との間には反強磁性層が設けられていないことを特徴とすることによって、耐食性に優れ、かつ軟磁気特性の良好な多層磁気抵抗効果膜が得られることを見出し、本発明を完成するに至った。

【０００６】また、本発明者らは、多層膜を用いた種々の構造を有する磁気抵抗効果型ヘッドについて鋭意研究を重ねた結果、基板と、非磁性層で分離された２層の磁性層とそのうちの一方の磁性層に接触して設けられた反強磁性層とを含む多層膜と、一対の電極とを備える磁気抵抗効果型ヘッドにおいて、反強磁性層は酸化物を主成分とし基板に対して２層の磁性層よりも遠い側に設けられており、反強磁性層に接触していない磁性層と基板との間には反強磁性層が設けられておらず、一対の電極は少なくとも反強磁性層以外の層に接触していることを特徴とすることによって前記目的を達成できることを見出し、本発明を完成するに至った。

【０００７】一対の電極を反強磁性層以外の層に接触して設けるには、酸化物系反強磁性層の一部を除去して電極を形成すればよい。すなわち、２層の磁性層及びそれらを分離する非磁性層を有し、一方の磁性層が反強磁性層に接触している多層膜を用いた磁気抵抗効果型ヘッドにおいて、酸化物を主成分とする高耐食性の反強磁性層を、多層膜を形成した基板から見て上記２層の磁性層よりも遠い側に形成する。さらに、電極を形成する部分の反強磁性層を除去した後、電極を形成する。このようなプロセスにより形成することにより、高感度、優れた軟磁気特性を示す磁気抵抗効果型ヘッドが得られる。

【０００８】さらに、基板と電極の間にＣｏ系合金、例えばＣｏ－１７ａｔ％Ｐｔ合金などのＣｏ－Ｐｔ系合金、Ｃｏ－Ｃｒ－Ｐｔ系合金、Ｃｏ－Ｃｒ－Ｔａ系合金等からなる高保磁力層を形成することにより、バルクハウゼンノイズの少ない磁気抵抗効果型ヘッドを得ることができる。また、上記磁気抵抗効果型ヘッドを磁気記録再生装置に用いるには、誘導型磁気ヘッドを組み合わせることが好ましい。

【０００９】

【作用】酸化物を主成分とする反強磁性層を用いることにより耐食性を高めることができる。また、反強磁性層を多層膜を形成した基板から見て２層の磁性層よりも遠い側に形成することにより、磁性層の軟磁気特性が向上する。電極を形成する部分の反強磁性層を除去した後、電極を形成することにより、多層膜にセンス電流を流すことが可能になる。

【００１０】また、基板と電極の間にＣｏ系合金からなる高保磁力層を形成することにより、多層膜を構成する磁性層にバイアス磁界を印加することが可能になり、この結果、磁気抵抗効果型ヘッドに生じやすいバルクハウゼンノイズを抑制することができる。また、上記磁気抵抗効果型ヘッドと誘導型磁気ヘッドを組み合わせることにより、高密度磁気記録に好ましい高性能磁気ヘッドを得ることができ、この結果、磁気記録再生装置の性能が著しく向上する。

【００１１】

【実施例】以下に本発明の実施例を挙げ、図面を参照しながらさらに具体的に説明する。

〔実施例１〕図２に断面構造を示す多層膜をイオンビームスパッタリング法を用いて形成した。到達真空度は、3×10^{-5}Ｐａ、スパッタリング時のＡｒ圧力は０．０２Ｐａとした。また、膜形成速度は、０．０１～０．０２ｎｍ／ｓとした。

【００１２】まず、比較例として、図２（ａ）に示すように、Ｓｉ（１００）からなる基板２１上に、厚さ５０ｎｍのＮｉ－Ｏ系酸化物からなる反強磁性層２２を形成し、さらにその上に、厚さ５．０ｎｍのＮｉ－２０ａｔ％Ｆｅからなる磁性層２３、厚さ２．５ｎｍのＣｕからなる非磁性層２４及び厚さ５．０ｎｍのＮｉ－２０ａｔ％Ｆｅからなる磁性層２５を順次積層した多層膜を形成した。反強磁性層２２は、ＮｉＯからなるターゲットを用いて形成した。Ｎｉと酸素の組成比はスパッタリングによって変化しているものと考えられるが、組成比が変化してもＮｉ－Ｏ系酸化物の層が室温で反強磁性を示せば多層膜における反強磁性材料として使用できるので問題はない。

【００１３】次に、本実施例による多層膜として、図２（ｂ）に示すように、Ｓｉ（１００）からなる基板２６上に、厚さ５．０ｎｍのＮｉ－２０ａｔ％Ｆｅからなる磁性層２７、厚さ２．５ｎｍのＣｕからなる非磁性層２

８を形成した後、厚さ５．０ｎｍのＮｉ－２０ａｔ％Ｆｅからなる磁性層２９及び厚さ５０ｎｍのＮｉ－Ｏ系からなる反強磁性層３０を順次積層した多層膜を形成した。反強磁性層２２は、前記比較例と同様にＮｉＯからなるターゲットを用いて形成した。

【００１４】すなわち、図２（ａ）に示す比較例においては、反強磁性層２２は多層膜を形成した基板２１から見て２層の磁性層２３，２５よりも近い側に形成されている。これに対し、図２（ｂ）に示す本実施例の多層膜では、反強磁性層３０は多層膜を形成した基板２６から見て２層の磁性層２７，２９よりも遠い側に形成されている。

【００１５】図２（ａ）及び図２（ｂ）に示す多層膜の磁化曲線を、それぞれ図３（ａ）及び図３（ｂ）に示す。前記フィジカル・レビュー・Ｂ（Physical Review B）にも記載されているように、反強磁性層に接していない磁性層の磁化反転により、零磁界付近で磁化の急激な変化が生じる。これに対し、反強磁性層に接している磁性層は、反強磁性層からの交換バイアス磁界を受けているため、磁化反転する磁界が８ｋＡ／ｍ程度、零磁界よりシフトしている。磁気抵抗効果型磁気ヘッドでは、反強磁性層に接していない磁性層の磁化反転により外部磁界を検出する。このため、反強磁性層に接していない磁性層の磁気特性が重要である。

【００１６】図３（ａ）に示すように、比較例の多層膜では、反強磁性層に接していない磁性層の保磁力は３２０Ａ／ｍである。これに対し、図３（ｂ）に示すように、本実施例の多層膜では、反強磁性層に接していない磁性層の保磁力は１６０Ａ／ｍと、比較例の多層膜での値の１／２になる。比較例の多層膜において、反強磁性層に接していない磁性層の保磁力が高くなる原因は以下のように推察される。すなわち、２層の磁性層の下部には、あらかじめ反強磁性層を形成する。この反強磁性層は厚さが厚いため、上部の表面に凹凸が生じる。このため、反強磁性層上に形成した磁性層の平坦性が低下し、磁性層の保磁力が高くなるものと思われる。これに対し、本実施例の多層膜では、平坦な基板上に磁性層を形成するため、磁性層の平坦性が向上し、優れた軟磁気特性を示すものと考えられる。ちなみに、比較例の多層膜の磁気抵抗変化率は３．５％であり、本実施例の多層膜の磁気抵抗変化率は３．３％であった。

【００１７】上述の多層膜の構造による磁性層の保磁力の違いは、磁性層として厚さ５．０ｎｍのＮｉ－１６ａｔ％Ｆｅ－１８ａｔ％Ｃｏ合金を用いた場合には、さらに大きかった。すなわち、反強磁性層に接していない磁性層の保磁力は、図２（ａ）に示す構造の多層膜では８００Ａ／ｍであり、図２（ｂ）に示す構造の多層膜では１６０Ａ／ｍであった。このように、上述の多層膜の構造による磁性層の保磁力の違いは、Ｎｉ－Ｆｅ系、Ｎｉ－Ｆｅ－Ｃｏ系の磁性材料に広く観測される。

【００１８】また、上述の多層膜の構造による磁性層の保磁力の違いは、反強磁性層として他の酸化物系を用いても同様である。他の酸化物系反強磁性材料としては、Ｃｏ－Ｏ系、Ｆｅ－Ｏ系、Ｎｉ－Ｃｏ－Ｏ系などが使用できる。しかし、ネール温度の高いＮｉ－Ｏ系酸化物が最も好ましい反強磁性材料である。

【００１９】〔実施例２〕前述のように、図２（ｂ）に示す構造の多層膜は、軟磁気特性が優れている。そこで、図２（ｂ）に示す構造の多層膜を用いて磁気抵抗効果素子を作製した。作製した磁気抵抗効果素子の断面構造を図１に示す。基板１１には、ガラスを用いた。バッファ層１２には、厚さ５．０ｎｍのＨｆを用いた。このバッファ層１２は、多層膜の軟磁気特性をさらに向上させる働きがある。また、厚さ５．０ｎｍのＮｉ－２０ａｔ％Ｆｅを磁性層１３及び１５とし、厚さ２．５ｎｍのＣｕを非磁性層１４とし、厚さ５０ｎｍのＮｉ－Ｏを反強磁性層１６とした。電極１７にはＣｕを用いた。

【００２０】本実施例の磁気抵抗効果素子の作製プロセスを以下に述べる。まず、図４（ａ）のように、基板４１上にバッファ層４２、磁性層４３、非磁性層４４、磁性層４５、及び反強磁性層４６を順次積層して多層膜を形成する。成膜はイオンビームスパッタリング法により、実施例１と同様の条件で行った。ここで、反強磁性層４６は酸化物を主成分とするため、電気抵抗率が高い。このため、単純に反強磁性層４６の上に電極を形成しても、センス電流を流すことができない。そこで、本実施例では次のようなプロセスによって電極を形成する。

【００２１】まず、図４（ｂ）に示すように、反強磁性層４６上にレジスト層４７を形成する。次に、図４（ｃ）のように、イオンミリングにより、レジスト層４７のない部分を除去する。さらに、図４（ｄ）のように、電極材料４８を基板４１上に真空蒸着で形成する。その後、図４（ｅ）のように、レジスト４７を除去することによってレジスト上の電極材料のみ除去し、電極４９を残す。

【００２２】このようにして作製した磁気抵抗効果素子の磁気特性を測定したところ、保磁力は磁化容易磁区方向で１８０Ａ／ｍ、磁化困難方向で６０Ａ／ｍであり、磁気抵抗変化率は３．２％であった。なお、本実施例では非磁性層としてＣｕを用いたが、Ｃｕに代えて電気抵抗率の低いＡｕ，Ａｇ，Ａｌを用いても同様の結果が得られる。しかし、磁性層として３ｄ遷移金属を用いる場合には、磁性層とのフェルミ面のマッチングの観点から、非磁性層はＣｕであることが好ましい。

【００２３】また、本実施例では、バッファ層１２として、Ｈｆを用いたが、実質的にＨｆを主成分とする非磁性合金であれば、上記実施例と同様の効果が得られる。また、バッファ層材料としては、Ｔｉ，Ｚｒ，Ｔａ，Ｎｂ、あるいは、これらを主成分とする合金が好ましい。

具体的には、全ての組成範囲のＨｆ－Ｚｒ，Ｈｆ－Ｔｉ、５０ａｔ％以上のＨｆを含むＨｆ－Ｎｂ，Ｈｆ－Ｔａ、７０ａｔ％以上のＨｆを含むＨｆ－Ｃｒ，Ｈｆ－Ｖ，Ｈｆ－Ｍｏ，Ｈｆ－Ｗ，Ｈｆ－Ｃｕ等の合金を使用することができる。これは、Ｈｆ，Ｔｉ，Ｚｒ，Ｔａ，Ｎｂ、あるいは、これらを主成分とする合金をバッファ層材料とすると、その上に形成される磁性層が強い（１１１）配向となり、磁性層が薄くても優れた軟磁気特性が得られるためである。

【００２４】また、図１の断面構造の多層膜として、Ｎｉ－Ｏ（５０ｎｍ）／Ｎｉ－２０ａｔ％Ｆｅ（３．０ｎｍ）／Ｃｏ（２．０ｎｍ）／Ｃｕ（２．５ｎｍ）／Ｎｉ－２０ａｔ％Ｆｅ（５．０ｎｍ）を用いると、磁気抵抗変化率が４．８％と高くなり、磁気抵抗効果素子の感度が向上した。同様に、図１の断面構造の多層膜としてＮｉ－Ｏ（５０ｎｍ）／Ｎｉ－２０ａｔ％Ｆｅ（３．０ｎｍ）／Ｃｏ（２．０ｎｍ）／Ｃｕ（２．５ｎｍ）／Ｃｏ（０．５ｎｍ）／Ｎｉ－２０ａｔ％Ｆｅ（４．５ｎｍ）を用いると、磁気抵抗変化率が６．０％と更に高くなった。これは、磁性層をＮｉ－Ｆｅ／ＣｏとしてＣｕ層との界面にＣｏ層を設けることにより、Ｎｉ－Ｆｅの優れた軟磁気特性とＣｏ層による高い磁気抵抗変化率を同時に利用できるためと考えられる。

【００２５】〔実施例３〕図５に断面構造を示す磁気抵抗効果素子を作製した。基板５１には、ガラスを用いた。バッファ層５２には、厚さ５．０ｎｍのＨｆを用いた。また、厚さ５．０ｎｍのＮｉ－２０ａｔ％Ｆｅを磁性層５３及び５５とし、厚さ２．５ｎｍのＣｕを非磁性層５４とし、厚さ５０ｎｍのＮｉ－Ｏを反強磁性層５６とした。電極５７にはＣｕを用いた。

【００２６】本実施例の磁気抵抗効果素子は、実施例１と同様のプロセスにより形成できる。すなわち、図４（ａ）のように基板５１上に多層膜を形成し、図４（ｂ）のようにその上にレジスト層を形成する。そして、レジスト層のない部分の多層膜を除去するとき、多層膜を完全に除去せず一部を残す。その後、図４（ｄ）及び図４（ｅ）に示すプロセスと同様のプロセスで電極５７を形成すると、本実施例の磁気抵抗効果素子が得られる。

【００２７】本発明の多層膜は、基本的には、多層膜と電極が電気的に接触すればセンス電流を流すことができる。すなわち、レジストのない部分の反強磁性層（絶縁層）のみ除去して、露出した磁性層（導電層）上に電極を形成すればよい。しかし、反強磁性層のみを除去することは、ミリングにおける終点判定が困難であるため現実的ではなく、実際には反強磁性層以外の多層膜の一部も除去することになる。また、多層膜だけでなく基板の一部も除去しても本発明の有効性を損なうことはない。本実施例の磁気抵抗効果素子の磁気特性を測定したところ、保磁力は磁化容易方向で１７０Ａ／ｍ、磁化困難方向で７０Ａ／ｍであり、磁気抵抗変化率は３．１％であった。

【００２８】〔実施例４〕図６に断面構造を示す磁気抵抗効果素子を形成した。基板６１には、ガラスを用いた。バッファ層６２には、厚さ５．０ｎｍのＨｆを用いた。また、厚さ５．０ｎｍのＮｉ－２０ａｔ％Ｆｅを磁性層６３及び６５、厚さ２．５ｎｍのＣｕを非磁性層６４、厚さ５０ｎｍのＮｉ－Ｏを反強磁性層６６とした。電極６７にはＣｕを用い、さらに、電極６７と基板６１との間に、厚さ５．０ｎｍのＣｏ－１７ａｔ％Ｐｔからなる磁性層６８を形成した。膜形成は前述の実施例と同様の方法で行った。

【００２９】Ｃｏ－１７ａｔ％Ｐｔからなる磁性層６８は、８０ｋＡ／ｍ程度の保磁力を示す高保磁力材料である。この高保磁力層は、磁性層６３のトラック幅方向、すなわち一対の電極６７，６７を結ぶ方向にバイアス磁界を印加するために設けた。本実施例の磁気抵抗効果素子と、高保磁力の磁性層６８がない以外は本実施例の磁気抵抗効果素子と同一の構造を有する比較用の磁気抵抗効果素子を各々３０個ずつ作製し、再生特性を調べた。その結果、高保磁力の磁性層６８を有しない比較用の素子は、３０個全ての再生信号にバルクハウゼンノイズが認められたのに対し、本実施例の素子でバルクハウゼンノイズが発生したのは５個のみであった。このように、磁性層６３に対するバイアス磁界の印加により、磁気抵抗効果素子のバルクハウゼンノイズを抑制することができた。

【００３０】本実施例では、ガラス基板６１はミリングされていないが、ガラス基板６１がミリングされても本発明の有効性を損なうことはない。また、磁性層６８として、他の高保磁力材料を用いることもできる。薄い層厚で高い保磁力を示す材料が好ましく、Ｃｏ系合金にこのような材料が多い。Ｃｏ系合金としては、Ｃｏ－Ｔａ－Ｐｔ、Ｃｏ－Ｃｒ－Ｐｔ、Ｃｏ－Ｃｒなどが好ましい。

【００３１】〔実施例５〕ＮｉＯ（５０ｎｍ）／Ｎｉ－Ｆｅ（３０ｎｍ）及びＦｅ－４０ａｔ％Ｍｎ（５０ｎｍ）／Ｎｉ－Ｆｅ（３０ｎｍ）の２種類の２層膜を形成した。それぞれの２層膜では、Ｎｉ－Ｆｅ系合金に反強磁性層からの交換バイアス磁界が印加される。

【００３２】これらの２層膜を温度６０℃、湿度９０％の環境におく耐食性試験を行った。耐食性試験により反強磁性層が完全に腐食されると、Ｎｉ－Ｆｅ系合金に交換バイアス磁界が印加されなくなる。従って、耐食性試験前の交換バイアス磁界と試験後の交換バイアス磁界とを比較することにより、反強磁性層の腐食された割合を測定することができる。

【００３３】図７に耐食性試験の結果を示す。この図において、試験前後の交換バイアス磁界の比が１．０の時、反強磁性層は全く腐食されないことを示す。また、

試験前後の交換バイアス磁界の比が０の時、反強磁性層が完全に腐食されたことを示す。図７のように、反強磁性層としてＦｅ－Ｍｎ系合金を用いると、１２５０時間の試験時間で反強磁性層が腐食し、交換バイアス磁界が零になる。これに対し、反強磁性層としてＮｉＯを用いると、１５００時間後においても反強磁性層は腐食されず、交換バイアス磁界は変化しない。この試験結果から明らかなように、ＮｉＯは耐食性に優れ、多層膜磁気抵抗効果素子に用いる反強磁性層材料として好ましい。

【００３４】〔実施例６〕本発明の磁気抵抗効果素子を用い、磁気ヘッドを作製した。磁気ヘッドの構造を以下に示す。図８は、本実施例による記録再生分離型ヘッドの一部分を切断した斜視図である。Al_2O_3・ＴｉＣを主成分とする焼結体をスライダ用の基板７７とした。基板７７の上に、スパッタリング法でＮｉ－２０ａｔ％Ｆｅ合金からなるシールド層７２を形成した。シールド層７２の膜厚は１．０μｍとした。シールド層７２の上にスパッタリング法により層厚０．１μｍのAl_2O_3からなるギャップ層を形成した後、図４に示したプロセスにより多層磁気抵抗効果膜７１及び電極７８からなる磁気抵抗効果素子を形成した。多層磁気抵抗効果膜７１としては、Ｎｉ－Ｏ（５０ｎｍ）／Ｎｉ－２０ａｔ％Ｆｅ（３．０ｎｍ）／Ｃｏ（２．０ｎｍ）／Ｃｕ（２．５ｎｍ）／Ｃｏ（０．５ｎｍ）／Ｎｉ－２０ａｔ％Ｆｅ（４．５ｎｍ）／Ｈｆ（５．０ｎｍ）を用いた。また、電極７８には、Ｃｒ／Ｃｕ／Ｃｒ／Ｃｏ－１７ａｔ％Ｐｔという多層構造の材料を用いた。電極の一部にＣｏ系合金を用いたのは、前記実施例４で述べたように、磁性層のトラック幅方向にバイアス磁界を印加し、バルクハウゼンノイズを抑制するためである。本実施例では、電極間隔は２．０μｍである。また、多層磁気抵抗効果膜７１の幅（磁気記録媒体面の法線方向の長さ）は、１．０μｍである。さらに、上述のギャップ層と同様のギャップ層を形成した後、スパッタリング法で、１．０μｍの膜厚を有するＮｉ－２０ａｔ％Ｆｅ合金からなるシールド層７３を形成した。以上、述べた部分が再生ヘッドとして働く。

【００３５】次に、厚さ約３μｍのAl_2O_3からなるギャップ層を形成した後、下部磁極７５、上部磁極７６及びコイル７４からなる記録ヘッドを形成した。下部磁極７５、上部磁極７６には、スパッタリング法で形成した膜厚３．０μｍのＮｉ－２０ａｔ％Ｆｅ合金を用いた。下部磁極７５及び上部磁極７６の間のギャップ層には、スパッタリング法で形成した膜厚０．２μｍのAl_2O_3を用いた。コイル７４には膜厚３μｍのＣｕを使用した。

【００３６】また、磁気ヘッド作製プロセスの研磨などの工程を全て行った後、磁気ヘッドに４００ｋＡ／ｍの磁界中で、２３０℃、１０分間の熱処理を行い、Ｎｉ－Ｏ系反強磁性層の交換バイアス磁界の向きを、磁気記録媒体面の法線方向とした。また、Ｎｉ－Ｏ系反強磁性層に接していない磁性層の磁化容易方向は、反強磁性層の交換バイアス磁界の向きとは直交する方向である。

【００３７】以上述べた構造の磁気ヘッドで記録再生実験を行った。磁気抵抗効果素子に流すセンス電流は2×10^7Ａ／cm^2とした。ほぼ同様の構造のＮｉ－Ｆｅ単層膜を用いた磁気ヘッド作製し、本発明の磁気ヘッドと出力を比較したところ、本発明の磁気ヘッドは、３．２倍高い再生出力を示した。これは、本発明の再生ヘッドに高磁気抵抗効果を示す多層膜を用いたためと考えられる。

【００３８】また、図２（ａ）に示す比較用の多層膜を用い、電極下部にＣｏ系の高保磁力材料層を設けた磁気ヘッドも作製したところ、本発明の磁気抵抗効果型ヘッドと同様出力は高いが、バルクハウゼンノイズが非常に頻繁に観測された。また、出力波形に歪が観測された。これは、図２（ａ）に示す比較用の多層膜の保磁力が高いためと考えられる。これに対し、本発明の磁気抵抗効果型ヘッドでは、バルクハウゼンノイズは頻繁には観測されず、また、出力波形には歪が観測されなかった。これは、本発明の磁気ヘッドでは、多層膜の上部にＮｉ－Ｏ系反強磁性層を形成しているため、磁性層の保磁力が低いためと考えられる。

【００３９】図２（ａ）に示す比較用の多層膜を使用した磁気ヘッドと、図２（ｂ）に示す多層構造を有する本発明の磁気ヘッドの特性の違いを更に明瞭に観察するため、各構造の多層膜にＣｏ系合金層を下部に設けた一対の電極を設けて磁気ヘッドを作製し、それぞれの磁気ヘッドにヘルムホルツコイルからの磁界を印加して出力電圧変化を測定した。この方法は、実際の磁気記録媒体の信号を検出するよりもバルクハウゼンノイズが発生しやすく、その点で厳しい実験であるといえる。

【００４０】図９（ａ）に、図２（ａ）に示す比較用の多層膜を使用した磁気ヘッドについての結果を示す。図のように、磁界に対して急激に電圧が変化している部分が観測される。これは、バルクハウゼンノイズによるものと考えられる。図２（ａ）に示す比較用の多層膜は保磁力が高い。このため、電極材料の最下部にＣｏ系の高保磁力材料を設け、磁性層のトラック幅方向にバイアス磁界を印加しても、バルクハウゼンノイズを抑止できなかったものと思われる。但し、電気抵抗の変化する領域が全体に負の磁界方向に変化している原因は不明である。

【００４１】図９（ｂ）に、図２（ｂ）に示す多層膜を使用した磁気ヘッドについての結果を示す。図から明らかなように、磁界を変化させても電圧の変化はスムーズであり、バルクハウゼンノイズは認められない。これは、図２（ｂ）に示す構造の多層膜が低い保磁力を有し、さらに、磁性層のトラック幅方向にバイアス磁界を印加したためと考えられる。

【００４２】〔実施例７〕実施例６で述べた本発明の磁気ヘッドを用い、磁気ディスク装置を作製した。図１０に、磁気ディスク装置の構造の概略図を示す。磁気記録媒体８１には、残留磁束密度０．７５ＴのＣｏ－Ｎｉ－Ｐｔ－Ｔａ系合金からなる材料を用いた。磁気記録媒体８１は駆動部８２によって回転駆動される。磁気ヘッド８３の記録ヘッドのトラック幅は３μｍ、再生ヘッドのトラック幅は２μｍとした。磁気ヘッド８３は、駆動部８４によって回動駆動されて磁気記録媒体８１上のトラックを選択できる。磁気ヘッド８３による記録再生信号は記録再生信号処理系８５で処理される。

【００４３】磁気ヘッド８３に用いた磁気抵抗効果素子は、従来のパーマロイ単層膜を用いた磁気抵抗効果素子の約３倍の出力を示すため、さらに、トラック幅が狭く、記録密度の高い磁気ディスク装置を作製することもできる。本発明の磁気ヘッドは、特に、１Ｇｂ／ｉｎ^{2}以上の記録密度を有する磁気記録再生装置に有効である。また、１０Ｇｂ／ｉｎ^{2}以上の記録密度を有する磁気記録再生装置には必須であると考えられる。

【００４４】

【発明の効果】本発明によると、高感度かつ優れた軟磁気特性を示す磁気抵抗効果型ヘッドが得られる。さらに、基板と電極の間にＣｏ系合金からなる高保磁力層を形成することにより、バルクハウゼンノイズの少ない磁気抵抗効果型ヘッドを得ることができる。また、上記磁気抵抗効果型ヘッドを誘導型磁気ヘッドと組み合わせることにより、高密度磁気記録再生装置に有利な高性能磁気ヘッドを得ることができる。

【図面の簡単な説明】

【図１】本発明の一実施例による磁気抵抗効果素子の構造を示す断面図。

【図２】本発明の多層膜及び比較用の多層膜の構造を示す断面図。

【図３】図２に示す本発明の多層膜及び比較用の多層膜のの磁化曲線を示すグラフ。

【図４】本発明の磁気抵抗効果素子の作製プロセスを示す図。

【図５】本発明の他の実施例による磁気抵抗効果素子の構造を示す断面図。

【図６】本発明の他の実施例による磁気抵抗効果素子の構造を示す断面図。

【図７】ＮｉＯ反強磁性層とＦｅ－Ｍｎ系合金反強磁性層に対する耐食性試験の結果を示す図。

【図８】本発明の磁気抵抗効果素子を用いた磁気ヘッドの構造を示す斜視図。

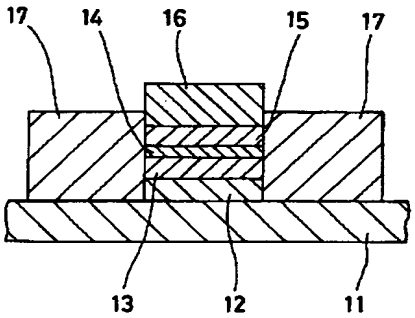
【図９】印加磁界に対する磁気ヘッドの電圧変化を示す図。

【図１０】磁気記録再生装置の概略図。

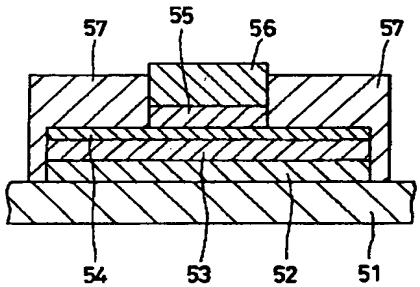
【符号の説明】

１１，２１，２６，４１，５１，６１，７７…基板
１２，４２，５２，６２…バッファ層
１３，１５，２３，２５，２７，２９，４３，４５，５３，５５，６３，６５，６８…磁性層
１４，２４，２８，４４，５４，６４…非磁性層
１６，２２，３０，４６，５６，６６…反強磁性層
１７，４９，５７，６７，７８…電極
４７…レジスト層
４８…電極材料
７１…多層磁気抵抗効果膜
７２，７３…シールド層
７４…コイル
７５…下部磁極
７６…上部磁極
８１…磁気記録媒体
８２…磁気記録媒体駆動部
８３…磁気ヘッド
８４…磁気ヘッド駆動部
８５…記録再生信号処理系

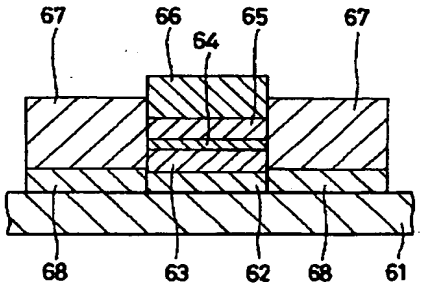
【図１】



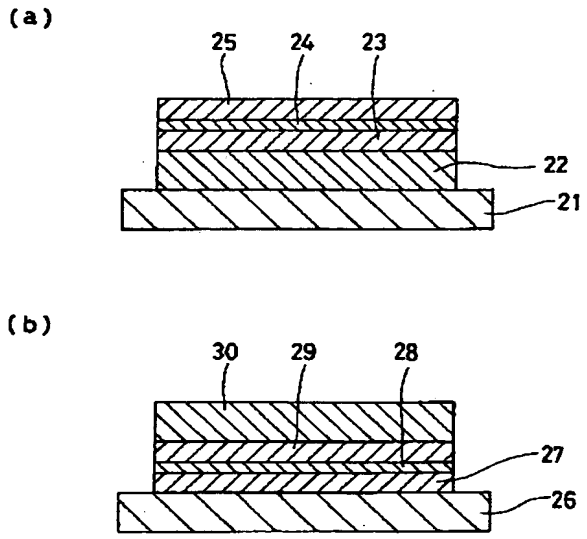
【図５】



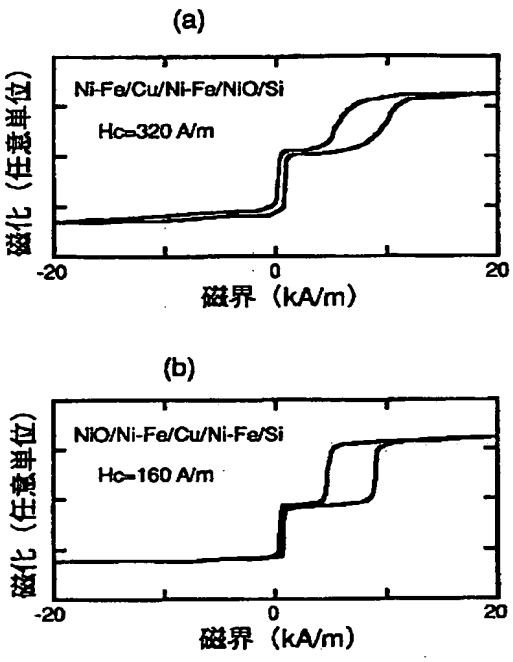
【図６】



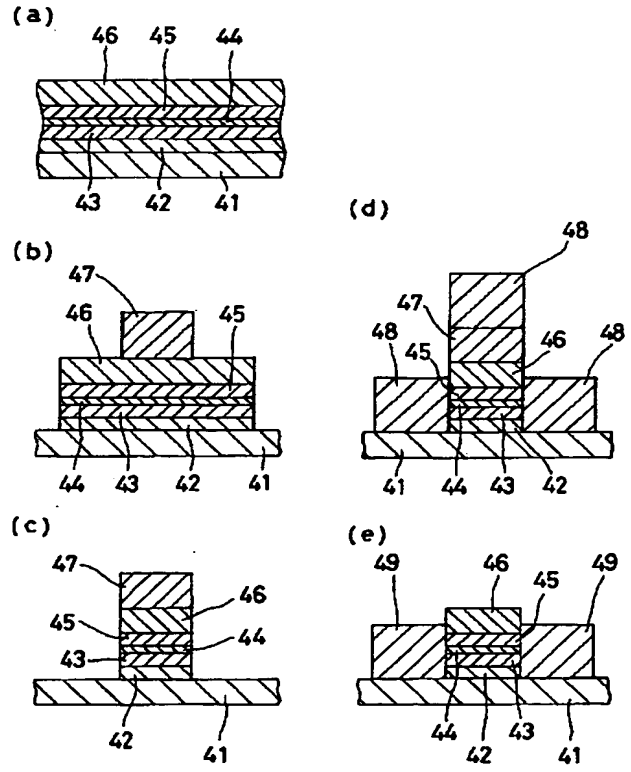
【図２】


(a)
25
24
23
22
21
(b)
30
29
28
27
26

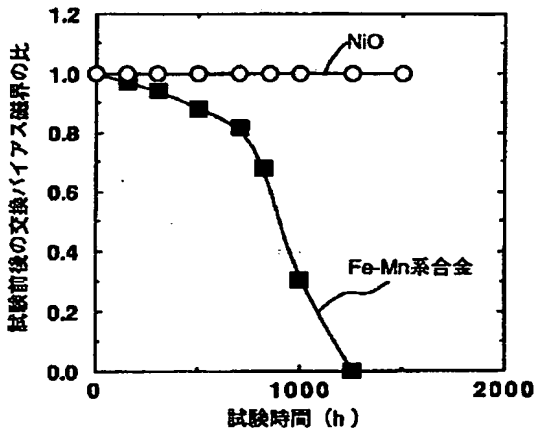
【図３】


(a)
Ni-Fe/Cu/Ni-Fe/NiO/Si
Hc=320 A/m
磁化（任意単位）
-20
0
20
磁界（kA/m）
(b)
NiO/Ni-Fe/Cu/Ni-Fe/Si
Hc=160 A/m
磁化（任意単位）
-20
0
20
磁界（kA/m）

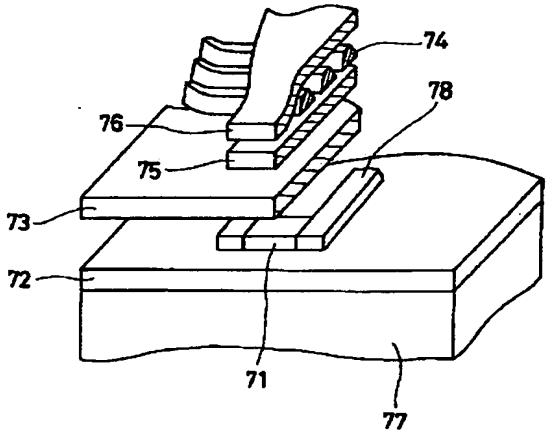
【図４】


(a)
46
45
44
43
42
41
(b)
47
46
45
44
43
42
41
(c)
47
46
45
44
43
42
41
(d)
48
47
48
45
46
48
41
44
43
42
(e)
49
46
45
49
44
42
43
41

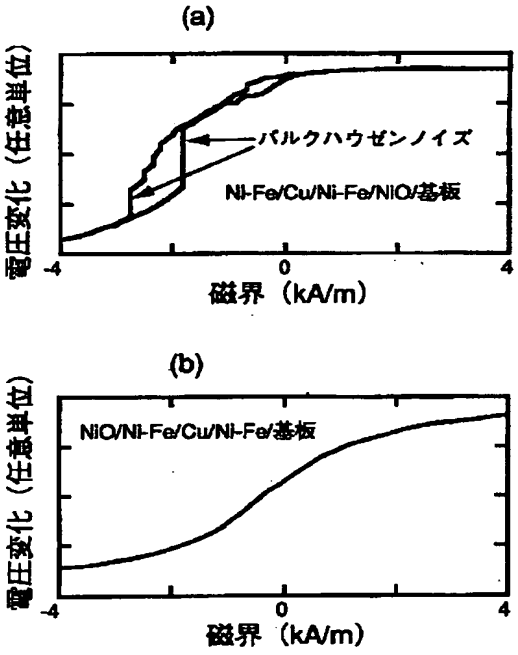
【図７】


1.2
1.0
0.8
0.6
0.4
0.2
0.0
試験前後の交換バイアス磁界の比
NiO
Fe-Mn系合金
0
1000
2000
試験時間（h）

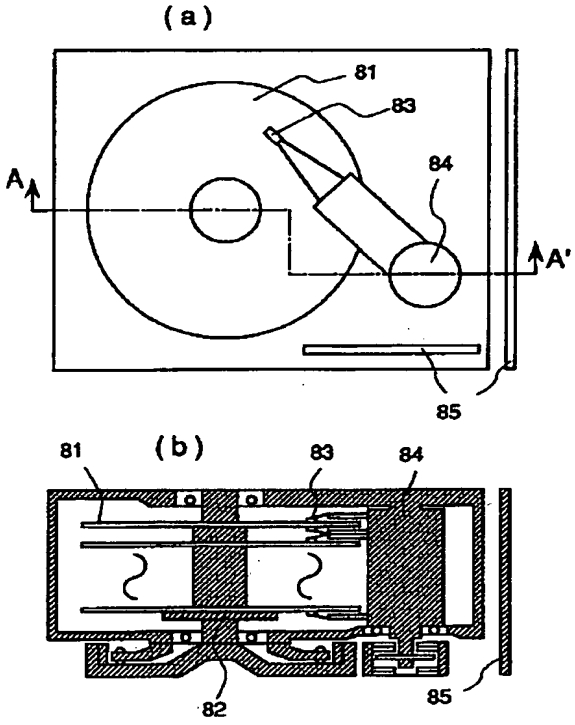
【図８】


74
78
76
75
73
72
71
77

【図９】


(a)
電圧変化（任意単位）
バルクハウゼンノイズ
Ni-Fe/Cu/Ni-Fe/NiO/基板
-4
0
4
磁界（kA/m）
(b)
電圧変化（任意単位）
NiO/Ni-Fe/Cu/Ni-Fe/基板
-4
0
4
磁界（kA/m）

【図１０】


(a)
81
83
84
A
A'
85
(b)
81
83
84
82
85

フロントページの続き

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(72) 発明者 濱川 佳弘
東京都国分寺市東恋ヶ窪一丁目280番地
株式会社日立製作所中央研究所内

(72) 発明者 鈴木 良夫
東京都国分寺市東恋ヶ窪一丁目280番地
株式会社日立製作所中央研究所内

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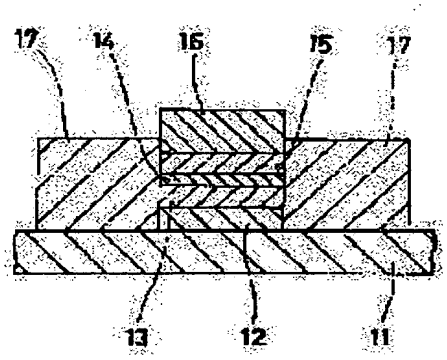
(71)Applicant : HITACHI LTD
(72)Inventor : NAKATANI RYOICHI
HOSHINO KATSUMI
HOSHIYA HIROYUKI
HAMAKAWA YOSHIHIRO
SUZUKI YOSHIO

(54) MAGNETO-RESISTANCE EFFECT FILM, MAGNETO-RESISTANCE EFFECT TYPE HEAD AND MAGNETIC RECORDING AND REPRODUCING DEVICE

(57)Abstract:
PURPOSE: To obtain a structure of a multilayered magneto-resistance effect element for which an oxide antiferromagnetic material is used.
CONSTITUTION: This magneto-resistance effect type head is constituted by using multilayered films, of which one layer of magnetic layer is impressed with the exchange bias magnetic field from the antiferromagnetic layer and one layer of the magnetic layer is not impressed with the exchange bias magnetic field from the antiferromagnetic layer, as the magneto-resistance effect material. The antiferromagnetic layer 16 consisting essentially of an oxide and having high corrosion resistance is formed on the side further from two layers of the material layers 13, 15 viewed from a substrate 11 formed with the multilayered films. Further, electrodes 17, 17 are formed after the antiferromagnetic layer of the part to be formed with the electrodes is removed. Then, the magneto- resistance effect element exhibits a high sensitivity and excellent soft magnetic characteristics. The high-performance magnetic head advantageous for a high- density magnetic recording and reproducing device is obtd. when this element is combined with an induction type magnetic head.



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CLAIMS

[Claim(s)]
[Claim 1] A two-layer magnetic layer prepared on a substrate, and a non-magnetic layer prepared between said two-layer magnetic layers, It consists of multilayers containing an antiferromagnetism layer contacted and prepared in one magnetic layer of said two-layer magnetic layers. Said antiferromagnetism layer is a multilayer magneto-resistive effect film which uses an oxide as a principal component and is characterized by being prepared in a far side rather than said two-layer magnetic layer to said substrate, and not preparing an antiferromagnetism layer between a magnetic layer which does not touch said antiferromagnetism layer, and said substrate.
[Claim 2] Multilayers containing an antiferromagnetism layer contacted and prepared in one magnetic layer of a substrate, a two-layer magnetic layer separated by non-magnetic layer, and these two-layer magnetic layers, Are a magneto-resistive effect mold arm head equipped with an electrode of a pair, and said antiferromagnetism layer uses an oxide as a principal component, and is prepared in a far side rather than said two-layer magnetic layer to said substrate. It is the magneto-resistive effect mold arm head which an antiferromagnetism layer is not prepared between a magnetic layer which does not touch said antiferromagnetism layer, and said substrate, but is characterized by an electrode of said pair touching a layer of said multilayers other than an antiferromagnetism layer at least.
[Claim 3] Multilayers containing an antiferromagnetism layer contacted and prepared in one magnetic layer of a substrate, a two-layer magnetic layer separated by non-magnetic layer, and these two-layer magnetic layers, It is the magneto-resistive effect mold arm head characterized by being a magneto-resistive effect mold arm head equipped with an electrode of a pair, and for said antiferromagnetism layer using an oxide as a principal component, preparing it in a far side rather than said two-layer magnetic layer to said substrate, and said antiferromagnetism layer not existing in the direction of a substrate normal of an electrode of said pair.
[Claim 4] Multilayers containing an antiferromagnetism layer contacted and prepared in one magnetic layer of a substrate, a two-layer magnetic layer separated by non-magnetic layer, and these two-layer magnetic layers, It is the magneto-resistive effect mold arm head characterized by being a magneto-resistive effect mold arm head equipped with an electrode of a pair, and for said antiferromagnetism layer using an oxide as a principal component, preparing it in a far side rather than said two-layer magnetic layer to said substrate, and said multilayers not existing in the direction of a substrate normal of an electrode of said pair.
[Claim 5] Multilayers containing an antiferromagnetism layer contacted and prepared in one magnetic layer of a substrate, a two-layer magnetic layer separated by non-magnetic layer, and these two-layer magnetic layers, Are a magneto-resistive effect mold arm head equipped with an electrode of a pair, and said antiferromagnetism layer uses an oxide as a principal component, and is prepared in a far side rather than said two-layer magnetic layer to said substrate. An electrode of said pair is a magneto-resistive effect mold arm head characterized by being in contact with said multilayers in a laminating end face of said multilayers.
[Claim 6] A magneto-resistive effect mold arm head of claim 2-5 characterized by forming a magnetic layer which consists of a Co system alloy between an electrode of said pair, and a

substrate given in any 1 term.
[Claim 7] A magneto-resistive effect mold arm head characterized by including multilayers prepared on a substrate by carrying out the laminating of the antiferromagnetism layer which uses a buffer layer, a magnetic layer, a non-magnetic layer, a magnetic layer, and an oxide as a principal component in this sequence, and an electrode of a pair prepared so that it might have a portion in contact with a laminating end face of said multilayers on said substrate.
[Claim 8] A magneto-resistive effect mold arm head characterized by forming a magnetic layer which consists of a Co system alloy between an electrode of said pair, and a substrate including multilayers prepared on a substrate by carrying out the laminating of the antiferromagnetism layer which uses a buffer layer, a magnetic layer, a non-magnetic layer, a magnetic layer, and an oxide as a principal component in this sequence, and an electrode of a pair prepared so that it might have a portion in contact with a laminating end face of said multilayers on said substrate.
[Claim 9] Said antiferromagnetism layer is the magneto-resistive effect mold arm head of claim 2-8 characterized by being a nickel-O system antiferromagnetism layer given in any 1 term.
[Claim 10] Said multilayers are the magneto-resistive effect mold arm heads of claim 2-9 characterized by being inserted between two-layer magnetic-shielding layers, and being prepared given in any 1 term.
[Claim 11] The compound-die magnetic head characterized by preparing combining a magneto-resistive effect mold arm head according to claim 10 and the induction type magnetic head equipped with a magnetic pole and a coil of a pair which were combined magnetically.
[Claim 12] A magnetic recorder and reproducing device characterized by including a driving means which drives relatively magnetic-recording data medium, the magnetic head given in any 1 term of claims 2-10, and said magnetic-recording data medium and said magnetic head, and a record regenerative-signal processor connected to said magnetic head.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the magneto-resistive effect mold arm head and magnetic recorder and reproducing device using the multilayer magneto-resistive effect film which has a high magneto-resistive effect, and its multilayer magneto-resistive effect film.
[0002]
[Description of the Prior Art] In connection with the densification of magnetic recording, the material in which high sensitivity is shown as a magneto-resistive effect material used for the magnetic head for playback is called for. Recently, the two-layer magnetic layer was separated by the non-magnetic layer like "the giant magneto-resistance in soft magnetism multilayers" (Giant Magnetoresistance in Soft Ferromagnetic Multilayers) of the physical review andB by Dieny and others (Physical Review B), the 43rd volume, No. 1, and a 1297-1300-page publication, and the method of impressing the exchange bias magnetic field from an antiferromagnetism layer to one magnetic layer was devised. Since these multilayers have the thin thickness of much more magnetic layer, its demagnetization factor when forming a magneto-resistive effect element is small, and, for this reason, they show a magneto-resistive effect by the low magnetic field. Moreover, magnetic-reluctance variation is also large.
[0003]
[Problem(s) to be Solved by the Invention] The antiferromagnetism layer which consists of a Fe-Mn system alloy is used for multilayers given in the above-mentioned physical review and B (Physical Review B). However, a Fe-Mn system alloy reduces the reliability of the magneto-resistive effect element corrosion resistance is bad and using it. Then, instead of a Fe-Mn system alloy, it is possible as an antiferromagnetism material to use oxide system antiferromagnetism materials, such as a corrosion resistance outstanding nickel-O system oxide. However, soft magnetic characteristics deteriorate and the magnetic layer formed on the oxide system antiferromagnetism layer reduces the sensitivity of a magneto-resistive effect element. Then, if an oxide system antiferromagnetism layer is formed on a magnetic layer, the soft magnetic characteristics of a magnetic layer will improve, but an oxide system antiferromagnetism layer cannot pass sense current, even if electrical resistivity is high and forms an electrode on multilayers.
[0004] The purpose of this invention is to offer high sensitivity magneto-resistive effect mold arm head and magnetic recorder and reproducing device using the high sensitivity multilayer magneto-resistive effect film excellent in corrosion resistance, and its multilayer magneto-resistive effect film.
[0005]
[Means for Solving the Problem] A two-layer magnetic layer prepared on a substrate as a result of this invention person's etc. repeating research wholeheartedly about a multilayer magneto-resistive effect film, It consists of multilayers containing a non-magnetic layer prepared between two-layer magnetic layers, and an antiferromagnetism layer contacted and prepared in one magnetic layer of the two-layer magnetic layers. By being characterized by for an antiferromagnetism layer using an oxide as a principal component, preparing it in a far side rather

than a two-layer magnetic layer to a substrate, and not preparing an antiferromagnetism layer between magnetic layers and substrates which do not touch an antiferromagnetism layer It came to complete a header and this invention for excelling in corrosion resistance and a multilayer magneto-resistive effect film with good soft magnetic characteristics being obtained.
[0006] As a result of repeating research wholeheartedly about a magneto-resistive effect mold arm head which has various structures where multilayers were used, this invention persons Moreover, a substrate, In a magneto-resistive effect mold arm head equipped with multilayers containing an antiferromagnetism layer contacted and prepared in a two-layer magnetic layer separated by non-magnetic layer, and one magnetic layer of them, and an electrode of a pair An antiferromagnetism layer uses an oxide as a principal component, and is prepared in a far side rather than a two-layer magnetic layer to a substrate. An antiferromagnetism layer is not prepared between magnetic layers and substrates which do not touch an antiferromagnetism layer, but an electrode of a pair came to complete a header and this invention for the ability of said purpose to be attained by being characterized by being in contact with layers other than an antiferromagnetism layer at least.
[0007] What is necessary is to remove a part of oxide system antiferromagnetism layer, and just to form an electrode, in order to contact and prepare an electrode of a pair in layers other than an antiferromagnetism layer. That is, it has a non-magnetic layer which separates a two-layer magnetic layer and them, and in a magneto-resistive effect mold arm head using multilayers in contact with an antiferromagnetism layer, one magnetic layer looks at an antiferromagnetism layer of high corrosion resistance which uses an oxide as a principal component from a substrate in which multilayers were formed, and forms it in a far side rather than the above-mentioned two-layer magnetic layer. Furthermore, an electrode is formed after removing an antiferromagnetism layer of a portion which forms an electrode. By forming according to such a process, a magneto-resistive effect mold arm head which shows high sensitivity and outstanding soft magnetic characteristics is obtained.
[0008] Furthermore, a magneto-resistive effect mold arm head with few Barkhausen noises can be obtained by forming a high coercive force layer which consists of Co-Pt system alloys, such as Co system alloy, for example, a Co-17at%Pt alloy etc., a Co-Cr-Pt system alloy, a Co-Cr-Ta system alloy, etc. between a substrate and an electrode. Moreover, in order to use the above-mentioned magneto-resistive effect mold arm head for a magnetic recorder and reproducing device, it is desirable to combine the induction type magnetic head.
[0009]
[Function] Corrosion resistance can be raised by using the antiferromagnetism layer which uses an oxide as a principal component. Moreover, the soft magnetic characteristics of a magnetic layer improve by seeing an antiferromagnetism layer from the substrate in which multilayers were formed, and forming in a far side rather than a two-layer magnetic layer. After removing the antiferromagnetism layer of the portion which forms an electrode, it becomes possible by forming an electrode to pass sense current to multilayers.
[0010] Moreover, the Barkhausen noise which it becomes possible to impress a bias magnetic field to the magnetic layer which constitutes multilayers, consequently is easy to produce on a magneto-resistive effect mold arm head can be controlled by forming the high coercive force layer which consists of a Co system alloy between a substrate and an electrode. Moreover, by combining the above-mentioned magneto-resistive effect mold arm head and the induction type magnetic head, the desirable high performance magnetic head can be obtained to high density magnetic recording, consequently the engine performance of a magnetic recorder and reproducing device improves remarkably.
[0011]
[Example] The example of this invention is given to below, and it explains still more concretely, referring to a drawing.
[Example 1] The multilayers which show cross-section structure were formed in drawing 2 using the ion beam sputtering method. The ultimate vacuum set 3x10 to 5 Pa, and Ar pressure at the time of sputtering to 0.02Pa. Moreover, film formation speed was made into 0.01 - 0.02 nm/s.
[0012] As an example of a comparison, as shown in drawing 2 (a), first, on the substrate 21

which consists of Si (100) The antiferromagnetism layer 22 which consists of a nickel-O system oxide with a thickness of 50nm is formed. Furthermore on it, the multilayers which carried out the laminating of the magnetic layer 25 which consists of nickel-20at%Fe with the magnetic layer 23 which consists of nickel-20at%Fe with a thickness of 5.0nm, a non-magnetic layer [24] which consists of Cu with a thickness of 2.5nm, and a thickness of 5.0nm one by one were formed. The antiferromagnetism layer 22 was formed using the target which consists of NiO. Although it is thought that the presentation ratio of nickel and oxygen is changing with sputtering, since it can be used as an antiferromagnetism material in multilayers if the layer of a nickel-O system oxide shows antiferromagnetism at a room temperature even if a presentation ratio changes, it is satisfactory.

[0013] As multilayers by this example, as shown in drawing 2 (b), next, on the substrate 26 which consists of Si (100) After forming the magnetic layer 27 which consists of nickel-20at%Fe with a thickness of 5.0nm, and the non-magnetic layer 28 which consists of Cu with a thickness of 2.5nm, The multilayers which carried out the laminating of the antiferromagnetism layer 30 which consists of a magnetic layer 29 which consists of nickel-20at%Fe with a thickness of 5.0nm, and a nickel-O system with a thickness of 50nm one by one were formed. The antiferromagnetism layer 22 was formed using the target which consists of NiO like said example of a comparison.

[0014] That is, in the example of a comparison shown in drawing 2 (a), the antiferromagnetism layer 22 is seen from the substrate 21 in which multilayers were formed, and is formed in the near side rather than the two-layer magnetic layers 23 and 25. On the other hand, in the multilayers of this example shown in drawing 2 (b), the antiferromagnetism layer 30 is seen from the substrate 26 in which multilayers were formed, and is formed in the far side rather than the two-layer magnetic layers 27 and 29.

[0015] The magnetization curve of the multilayers shown in drawing 2 (a) and drawing 2 (b) is shown in drawing 3 (a) and drawing 3 (b), respectively. The abrupt change of magnetization arises near a zero magnetic field by the flux reversal of the magnetic layer which is not in contact with an antiferromagnetism layer as indicated by said physical review and B (Physical Review B). On the other hand, since the magnetic layer which is in contact with the antiferromagnetism layer has received the exchange bias magnetic field from an antiferromagnetism layer, the magnetic field which carries out flux reversal has shifted it from 8kA/about m, and a zero magnetic field. In the magneto-resistive effect mold magnetic head, the flux reversal of the magnetic layer which is not in contact with an antiferromagnetism layer detects an external magnetic field. For this reason, the magnetic properties of the magnetic layer which is not in contact with an antiferromagnetism layer are important.

[0016] As shown in drawing 3 (a), in the multilayers of the example of a comparison, the coercive force of the magnetic layer which is not in contact with an antiferromagnetism layer is 320 A/m. On the other hand, as shown in drawing 3 (b), in the multilayers of this example, the coercive force of the magnetic layer which is not in contact with an antiferromagnetism layer is set to one half of the values in 160 A/m and the multilayers of the example of a comparison. In the multilayers of the example of a comparison, the cause by which the coercive force of the magnetic layer which is not in contact with an antiferromagnetism layer becomes high is guessed as follows. That is, an antiferromagnetism layer is beforehand formed in the lower part of a two-layer magnetic layer. Since this antiferromagnetism layer has thick thickness, irregularity produces it on the surface of the upper part. For this reason, the surface smoothness of the magnetic layer formed on the antiferromagnetism layer falls, and it is thought that the coercive force of a magnetic layer becomes high. On the other hand, by the multilayers of this example, in order to form a magnetic layer on a flat substrate, the surface smoothness of a magnetic layer improves and is considered that outstanding soft magnetic characteristics are shown. Incidentally, the magnetic-reluctance rate of change of the multilayers of the example of a comparison was 3.5%, and the magnetic-reluctance rate of change of the multilayers of this example was 3.3%.

[0017] The difference in the coercive force of the magnetic layer by the structure of above-mentioned multilayers was still greater when a nickel-16at%Fe-18at%Co alloy with a thickness of 5.0nm was used as a magnetic layer. That is, the coercive force of the magnetic layer which is

not in contact with an antiferromagnetism layer was 800 A/m in the multilayers of the structure shown in drawing 2 (a), and was 160 A/m in the multilayers of the structure shown in drawing 2 (b). Thus, the difference in the coercive force of the magnetic layer by the structure of above-mentioned multilayers is widely observed by the magnetic material of a nickel-Fe system and a nickel-Fe-Co system.

[0018] Moreover, even if the difference in the coercive force of the magnetic layer by the structure of above-mentioned multilayers uses other oxide systems as an antiferromagnetism layer, it is the same. As other oxide system antiferromagnetism materials, a Co-O system, a Fe-O system, a nickel-Co-O system, etc. can be used. However, a nickel-O system oxide with high Neel temperature is the most desirable antiferromagnetism material.

[0019] [Example 2] As mentioned above, the multilayers of the structure shown in drawing 2 (b) are excellent in soft magnetic characteristics. Then, the magneto-resistive effect element was produced using the multilayers of the structure shown in drawing 2 (b). The cross-section structure of the produced magneto-resistive effect element is shown in drawing 1 . Glass was used for the substrate 11. Hf with a thickness of 5.0nm was used for the buffer layer 12. This buffer layer 12 has the work which raises the soft magnetic characteristics of multilayers further. Moreover, nickel-20at%Fe with a thickness of 5.0nm was used as magnetic layers 13 and 15, Cu with a thickness of 2.5nm was used as the non-magnetic layer 14, and nickel-O with a thickness of 50nm was used as the antiferromagnetism layer 16. Cu was used for the electrode 17.

[0020] The production process of the magneto-resistive effect element of this example is described below. First, like drawing 4 (a), on a substrate 41, the laminating of a buffer layer 42, a magnetic layer 43, a non-magnetic layer 44, a magnetic layer 45, and the antiferromagnetism layer 46 is carried out one by one, and multilayers are formed. Membrane formation was performed on the same conditions as an example 1 by the ion beam sputtering method. Here, the antiferromagnetism layer 46 has high electrical resistivity in order to use an oxide as a principal component. For this reason, sense current cannot be passed even if it forms an electrode on the antiferromagnetism layer 46 simply. So, in this example, an electrode is formed according to the following processes.

[0021] First, as shown in drawing 4 (b), the resist layer 47 is formed on the antiferromagnetism layer 46. Next, ion milling removes a portion without the resist layer 47 like drawing 4 (c). Furthermore, an electrode material 48 is formed with vacuum deposition on a substrate 41 like drawing 4 (d). Then, like drawing 4 (e), by removing a resist 47, only the electrode material on a resist is removed and it leaves an electrode 49.

[0022] Thus, when the magnetic properties of the produced magneto-resistive effect element were measured, coercive force was 60 A/m in 180 A/m and a hard direction of magnetization in the direction of a magnetization easy magnetic domain, and magnetic-reluctance rate of change was 3.2%. In addition, although Cu was used as a non-magnetic layer in this example, the same result is obtained, even if it replaces with Cu and uses Au, Ag, and aluminum with low electrical resistivity. However, when using 3d transition metals as a magnetic layer, as for the viewpoint of matching of a Fermi surface with a magnetic layer to a non-magnetic layer, it is desirable that it is Cu.

[0023] Moreover, in this example, although Hf was used, if it is the nonmagnetic alloy which uses Hf as a principal component substantially as a buffer layer 12, the same effect as the above-mentioned example will be acquired. Moreover, as a buffer layer material, Ti, Zr, Ta, Nb, or the alloy that makes these a principal component is desirable. Specifically, alloys, such as Hf-Zr of all presentation ranges, Hf-Ti, Hf-Nb containing Hf beyond 50at%, Hf-Ta, Hf-Cr containing Hf beyond 70at%, Hf-V, Hf-Mo, Hf-W, and Hf-Cu, can be used. This is because the soft magnetic characteristics which were excellent even if the magnetic layer formed on it became strong (111) orientation and the magnetic layer was thin are obtained, when Hf, Ti, Zr, Ta, Nb, or the alloy that makes these a principal component is used as a buffer layer material.

[0024] Moreover, as multilayers of the cross-section structure of drawing 1 , when nickel-O (50nm)/nickel-20at%Fe(3.0nm)/Co(2.0nm)/Cu(2.5nm)/nickel-20at%Fe (5.0nm) was used, magnetic-reluctance rate of change became high with 4.8%, and the sensitivity of a magneto-resistive effect element improved. Similarly, when nickel-O(50nm)/nickel-20at%Fe(3.0nm)/Co

(2.0nm)/Cu(2.5nm)/Co(0.5nm)/nickel-20at%Fe (4.5nm) was used as multilayers of the cross-section structure of drawing 1 , magnetic-reluctance rate of change became still higher with 6.0%. This is considered because the high magnetic-reluctance rate of change by the soft magnetic characteristics and Co layer which were excellent in nickel-Fe can be used for coincidence by preparing Co layer in an interface with Cu layer by making a magnetic layer into nickel-Fe/Co.

[0025] [Example 3] The magneto-resistive effect element which shows cross-section structure to drawing 5 was produced. Glass was used for the substrate 51. Hf with a thickness of 5.0nm was used for the buffer layer 52. Moreover, nickel-20at%Fe with a thickness of 5.0nm was used as magnetic layers 53 and 55, Cu with a thickness of 2.5nm was used as the non-magnetic layer 54, and nickel-O with a thickness of 50nm was used as the antiferromagnetism layer 56. Cu was used for the electrode 57.

[0026] The magneto-resistive effect element of this example can be formed according to the same process as an example 1. That is, multilayers are formed on a substrate 51 like drawing 4 (a), and a resist layer is formed on it like drawing 4 (b). And when removing the multilayers of a portion without a resist layer, multilayers are not removed completely but it leaves a part. Then, if an electrode 57 is formed in the process shown in drawing 4 (d) and drawing 4 (e), and the same process, the magneto-resistive effect element of this example will be obtained.

[0027] Fundamentally, the multilayers of this invention can pass sense current, if an electrode contacts multilayers electrically. Namely, what is necessary is to remove only the antiferromagnetism layer (insulating layer) of a portion without a resist, and just to form an electrode on the exposed magnetic layer (conductive layer). However, since the end point judging in milling is difficult, it is not realistic to remove only an antiferromagnetism layer, and some multilayers other than an antiferromagnetism layer will be removed in fact. Moreover, even if it removes not only multilayers but some substrates, the effectiveness of this invention is not spoiled. When the magnetic properties of the magneto-resistive effect element of this example were measured, coercive force was 70 A/m in 170 A/m and a hard direction of magnetization in the easy direction of magnetization, and magnetic-reluctance rate of change was 3.1%.

[0028] [Example 4] The magneto-resistive effect element which shows cross-section structure was formed in drawing 6 . Glass was used for the substrate 61. Hf with a thickness of 5.0nm was used for the buffer layer 62. Moreover, nickel-O with a non-magnetic layer [64] and a thickness of 50nm was used [nickel-20at%Fe with a thickness of 5.0nm] as the antiferromagnetism layer 66 for Cu with a magnetic layers [63 and 65] and a thickness of 2.5nm. The magnetic layer 68 which consists of Co-17at%Pt with a thickness of 5.0nm between an electrode 67 and a substrate 61 was further formed in the electrode 67 using Cu. Film formation was performed by the same method as the above-mentioned example.

[0029] The magnetic layer 68 which consists of Co-17at%Pt is a high coercive force material in which the coercive force of 80 kA/m degree is shown. This high coercive force layer was prepared in order to impress a bias magnetic field in the truck cross direction of a magnetic layer 63, i.e., the direction to which the electrodes 67 and 67 of a pair are connected. Except that there were not the magneto-resistive effect element of this example and the magnetic layer 68 of high coercive force, it produced respectively at a time 30 magneto-resistive effect elements for a comparison which have the same structure as the magneto-resistive effect element of this example, and reproducing characteristics were investigated. Consequently, it was only five pieces that the Barkhausen noise generated the element for a comparison which does not have the magnetic layer 68 of high coercive force with the element of this example to the Barkhausen noise having been accepted in all 30 regenerative signals. Thus, the Barkhausen noise of a magneto-resistive effect element was able to be controlled by impression of a bias magnetic field to a magnetic layer 63.

[0030] In this example, although milling of the glass substrate 61 is not carried out, even if milling of the glass substrate 61 is carried out, it does not spoil the effectiveness of this invention. Moreover, other high coercive force materials can also be used as a magnetic layer 68. The material in which high coercive force is shown by film thickness is desirable, and Co system alloy has many such materials. As a Co system alloy, Co-Ta-Pt, Co-Cr-Pt, Co-Cr, etc. are desirable.

[0031] [Example 5] Two kinds of two-layer films, NiO(50nm)/nickel-Fe (30nm) and Fe-40at%Mn (50nm)/nickel-Fe (30nm), were formed. By each two-layer film, the exchange bias magnetic field from an antiferromagnetism layer is impressed to a nickel-Fe system alloy.
[0032] The corrosion resistance test which sets these two-layer films by the environment of the temperature of 60 degrees C and 90% of humidity was performed. If an antiferromagnetism layer is completely corroded by the corrosion resistance test, an exchange bias magnetic field will no longer be impressed to a nickel-Fe system alloy. Therefore, the rate that the antiferromagnetism layer was corroded can be measured by comparing the exchange bias magnetic field before a corrosion resistance test with the exchange bias magnetic field after a trial.
[0033] The result of a corrosion resistance test is shown in drawing 7 . In this drawing, when the ratio of the exchange bias magnetic field before and behind a trial is 1.0, it is shown that an antiferromagnetism layer is not corroded at all. Moreover, when the ratio of the exchange bias magnetic field before and behind a trial is 0, it is shown that the antiferromagnetism layer was corroded completely. Like drawing 7 , if a Fe-Mn system alloy is used as an antiferromagnetism layer, an antiferromagnetism layer will corrode in the test time of 1250 hours, and an exchange bias magnetic field will become zero. On the other hand, if NiO is used as an antiferromagnetism layer, an antiferromagnetism layer will not be corroded 1500 hours after and an exchange bias magnetic field will not change. NiO is desirable as an antiferromagnetism layer material which is excellent in corrosion resistance and is used for a multilayers magneto-resistive effect element so that clearly from this test result.
[0034] [Example 6] The magnetic head was produced using the magneto-resistive effect element of this invention. The structure of the magnetic head is shown below. Drawing 8 is the perspective diagram which cut a part of record playback discrete-type arm head by this example. The sintered compact which uses aluminum 2O3 and TiC as a principal component was used as the substrate 77 for sliders. On the substrate 77, the shield layer 72 which consists of a nickel-20at%Fe alloy by the sputtering method was formed. The thickness of the shield layer 72 could be 1.0 micrometers. the shield layer 72 top — the sputtering method — aluminum 2O3 of 0.1 micrometers of thickness from — after forming the becoming gap layer, the magneto-resistive effect element which consists of a multilayer magneto-resistive effect film 71 and an electrode 78 according to the process shown in drawing 4 was formed. As a multilayer magneto-resistive effect film 71, nickel-O(50nm)/nickel-20at%Fe(3.0nm)/Co(2.0nm)/Cu(2.5nm)/Co (0.5nm)/nickel-20at%Fe(4.5nm)/Hf (5.0nm) was used. Moreover, the material of the multilayer structure of Cr/Cu/Cr/Co-17at%Pt was used for the electrode 78. Co system alloy was used for some electrodes for impressing a bias magnetic field crosswise [of a magnetic layer / truck], and controlling a Barkhausen noise, as said example 4 described. In this example, an electrode spacing is 2.0 micrometers. Moreover, the width of face (normal lay length of a magnetic-recording data-medium side) of the multilayer magneto-resistive effect film 71 is 1.0 micrometers. Furthermore, after forming an above-mentioned gap layer and the same gap layer, the shield layer 73 which consists of a nickel-20at%Fe alloy which has 1.0-micrometer thickness by the sputtering method was formed. As mentioned above, the described portion works as the reproducing head.
[0035] next, aluminum 2O3 with a thickness of about 3 micrometers from — after forming the becoming gap layer, the recording head which consists of the lower magnetic pole 75, an up magnetic pole 76, and a coil 74 was formed. The nickel-20at%Fe alloy of 3.0 micrometers of thickness formed by the sputtering method was used for the lower magnetic pole 75 and the up magnetic pole 76. aluminum 2O3 of 0.2 micrometers of thickness formed in the gap layer between the lower magnetic pole 75 and the up magnetic pole 76 by the sputtering method It used. Cu of 3 micrometers of thickness was used for the coil 74.
[0036] Moreover, after performing all production processes, such as polishing of a magnetic-head production process, in the magnetic field of 400 kA/m, 230 degrees C and heat treatment for 10 minutes were performed, and the sense of the exchange bias magnetic field of a nickel-O system antiferromagnetism layer was made into the direction of a normal of a magnetic-recording data-medium side at the magnetic head. Moreover, the sense of the exchange bias magnetic field of an antiferromagnetism layer of the easy direction of magnetization of the magnetic layer which is

not in contact with a nickel-O system antiferromagnetism layer is a direction which intersects perpendicularly.
[0037] The record playback experiment was conducted by the magnetic head of the structure described above. The sense current passed for a magneto-resistive effect element is 2x107 A/cm2. It carried out. When [which used the nickel-Fe monolayer of the almost same structure] magnetic-head production was carried out and the magnetic head and the output of this invention were measured, the magnetic head of this invention showed the 3.2 times higher playback output. Since the multilayers which show a high magneto-resistive effect were used for the reproducing head of this invention, this is considered.
[0038] Moreover, although the output was high like the magneto-resistive effect mold arm head of this invention when the magnetic head which prepared the high coercive force material layer of Co system in the electrode lower part was also produced using the multilayers for a comparison shown in drawing 2 (a), the Barkhausen noise was observed very frequently. Moreover, distortion was observed by the output wave. Since the coercive force of the multilayers for a comparison shown in drawing 2 (a) is high, this is considered. On the other hand, with the magneto-resistive effect mold arm head of this invention, the Barkhausen noise was not observed frequently and distortion was not observed by the output wave. By the magnetic head of this invention, since the nickel-O system antiferromagnetism layer is formed in the upper part of multilayers, this is considered because the coercive force of a magnetic layer is low.
[0039] In order to observe still more clearly the difference in the property of the magnetic head which used the multilayers for a comparison shown in drawing 2 (a), and the magnetic head of this invention which has the multilayer structure shown in drawing 2 (b), the electrode of the pair which prepared Co system alloy layer in the lower part was prepared in the multilayers of each structure, the magnetic head was produced, the magnetic field from Helmholtz coils was impressed to each magnetic head, and output voltage change was measured. A Barkhausen noise tends to generate this method rather than it detects the signal of actual magnetic-recording data medium, and it can be said at that point that it is a severe experiment.
[0040] The result about the magnetic head which used the multilayers for a comparison shown in drawing 2 (a) for drawing 9 (a) is shown. As shown in drawing, the portion from which voltage is changing rapidly to a magnetic field is observed. This is considered to be based on a Barkhausen noise. The multilayers for a comparison shown in drawing 2 (a) have high coercive force. For this reason, even if it prepares the high coercive force material of Co system in the bottom of an electrode material and impresses a bias magnetic field crosswise [of a magnetic layer / truck], it is thought that a Barkhausen noise was not able to be inhibited. However, the cause of changing to the whole in the negative direction of a magnetic field has the unknown field where electric resistance changes.
[0041] The result about the magnetic head which used the multilayers shown in drawing 2 (b) for drawing 9 (b) is shown. Even if it changes a magnetic field so that clearly from drawing, change of voltage is smooth and a Barkhausen noise is not accepted. Since the multilayers of the structure shown in drawing 2 (b) have low coercive force and the bias magnetic field was impressed further crosswise [of a magnetic layer / truck], this is considered.
[0042] [Example 7] The magnetic disk drive was produced using the magnetic head of this invention stated in the example 6. The schematic diagram of the structure of a magnetic disk drive is shown in drawing 10 . The material which consists of a Co-nickel-Pt-Ta system alloy of residual magnetic flux density 0.75T was used for magnetic-recording data medium 81. The rotation drive of magnetic-recording data medium 81 is carried out by the mechanical component 82. The width of recording track of the recording head of the magnetic head 83 set the width of recording track of 3 micrometers and the reproducing head to 2 micrometers. A rotation drive is carried out by the mechanical component 84, and the magnetic head 83 can choose the truck on magnetic-recording data medium 81 by it. The record regenerative signal by the magnetic head 83 is processed by the record regenerative-signal processor 85.
[0043] Since the magneto-resistive effect element used for the magnetic head 83 shows the element about 3 times the output of a magneto-resistive effect which used the conventional permalloy monolayer, its width of recording track is still narrower, and it can also produce a

magnetic disk drive with high recording density. Especially the magnetic head of this invention is 1 Gb/in2. It is effective in the magnetic recorder and reproducing device which has the above recording density. Moreover, 10 Gb/in2 To be indispensable is considered by the magnetic recorder and reproducing device which has the above recording density.

[0044]

[Effect of the Invention] According to this invention, the magneto-resistive effect mold arm head which shows high sensitivity and outstanding soft magnetic characteristics is obtained. Furthermore, a magneto-resistive effect mold arm head with few Barkhausen noises can be obtained by forming the high coercive force layer which consists of a Co system alloy between a substrate and an electrode. Moreover, the high performance magnetic head advantageous to a high density magnetic recorder and reproducing device can be obtained by combining the above-mentioned magneto-resistive effect mold arm head with the induction type magnetic head.

[Translation done.]